AFRL-VA-WP-TM-2004-3011

SMI UAV CONFERENCE, LONDON, UK (9-10 FEB 2004)

MAJ Bryan Coon

Control Sciences Division (AFRL/VAC)
Air Vehicles Directorate
Air Force Research Laboratory
Air Force Materiel Command
Wright-Patterson Air Force Base, OH 45433-7542

FEBRUARY 2004

Final Report for 09 February 2004 – 10 February 2004

STINFO FINAL REPORT

AIR VEHICLES DIRECTORATE
AIR FORCE MATERIEL COMMAND
AIR FORCE RESEARCH LABORATORY
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433-7542

NOTICE

USING GOVERNMENT DRAWINGS, SPECIFICATIONS, OR OTHER DATA INCLUDED IN THIS DOCUMENT FOR ANY PURPOSE OTHER THAN GOVERNMENT PROCUREMENT DOES NOT IN ANY WAY OBLIGATE THE U.S. GOVERNMENT. THE FACT THAT THE GOVERNMENT FORMULATED OR SUPPLIED THE DRAWINGS, SPECIFICATIONS, OR OTHER DATA DOES NOT LICENSE THE HOLDER OR ANY OTHER PERSON OR CORPORATION; OR CONVEY ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE, OR SELL ANY PATENTED INVENTION THAT MAY RELATE TO THEM.

THIS REPORT HAS BEEN REVIEWED BY THE OFFICE OF PUBLIC AFFAIRS (ASC/PA) AND IS RELEASABLE TO THE NATIONAL TECHNICAL INFORMATION SERVICE (NTIS). AT NTIS, IT WILL BE AVAILABLE TO THE GENERAL PUBLIC, INCLUDING FOREIGN NATIONS.

THIS TECHNICAL REPORT HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION.

/s/

ENGINEER'S NAME
Ba Nguyen
AAR Technology Team
Control Systems Development and
Applications Branch

/s/

SUPERVISOR'S NAME
Yvette Weber
AAR Technology Team
Chief, Control Systems Development
and Applications Branch

/s/

NAME
Brian Van Vliet
Chief, Control Sciences Division

COPIES OF THIS REPORT SHOULD NOT BE RETURNED UNLESS RETURN IS REQUIRED BY SECURITY CONSIDERATIONS, CONTRACTUAL OBLIGATIONS, OR NOTICE ON A SPECIFIC DOCUMENT.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
February 2004	Conference Paper Preprint	02/09/2004 – 02/10/2004

4. TITLE AND SUBTITLE
SMI UAV CONFERENCE, LONDON, UK (9-10 FEB 2004)

5a. CONTRACT NUMBER
In-house

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
N/A

6. AUTHOR(S)
MAJ Bryan Coon

5d. PROJECT NUMBER
N/A

5e. TASK NUMBER
N/A

5f. WORK UNIT NUMBER
N/A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Control Sciences Division (AFRL/VAC)
Air Vehicles Directorate
Air Force Research Laboratory
Air Force Materiel Command
Wright-Patterson Air Force Base, OH 45433-7542

8. PERFORMING ORGANIZATION REPORT NUMBER
AFRL-VA-WP-TM-2004-3011

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Vehicles Directorate
Air Force Research Laboratory
Air Force Materiel Command
Wright-Patterson Air Force Base, OH 45433-7542

10. SPONSORING/MONITORING AGENCY ACRONYM(S)
AFRL/VAC

11. SPONSORING/MONITORING AGENCY REPORT NUMBER(S)
AFRL-VA-WP-TM-2004-3011

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Slideshow to be presented at the SMI UAV Conference, London, UK, 9-10 February 2004. This technical memo is a series of briefing charts, comprising the final briefing for this work effort.

Technical memo contains color.

14. ABSTRACT
The information is for a UAV conference in front of an international audience. This will be a top-level technology portfolio briefing.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT:	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON (Monitor)
a. REPORT	b. ABSTRACT	c. THIS PAGE			MAJ Bryan Coon
Unclassified	Unclassified	Unclassified	SAR	34	19b. TELEPHONE NUMBER *(Include Area Code)* (937) 656-6355

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18

Air Vehicles Directorate

SMI UAV Conference, London, UK (9-10 Feb 2004)

Col Michael B. Leahy, Jr.

Director

Air Vehicles Directorate

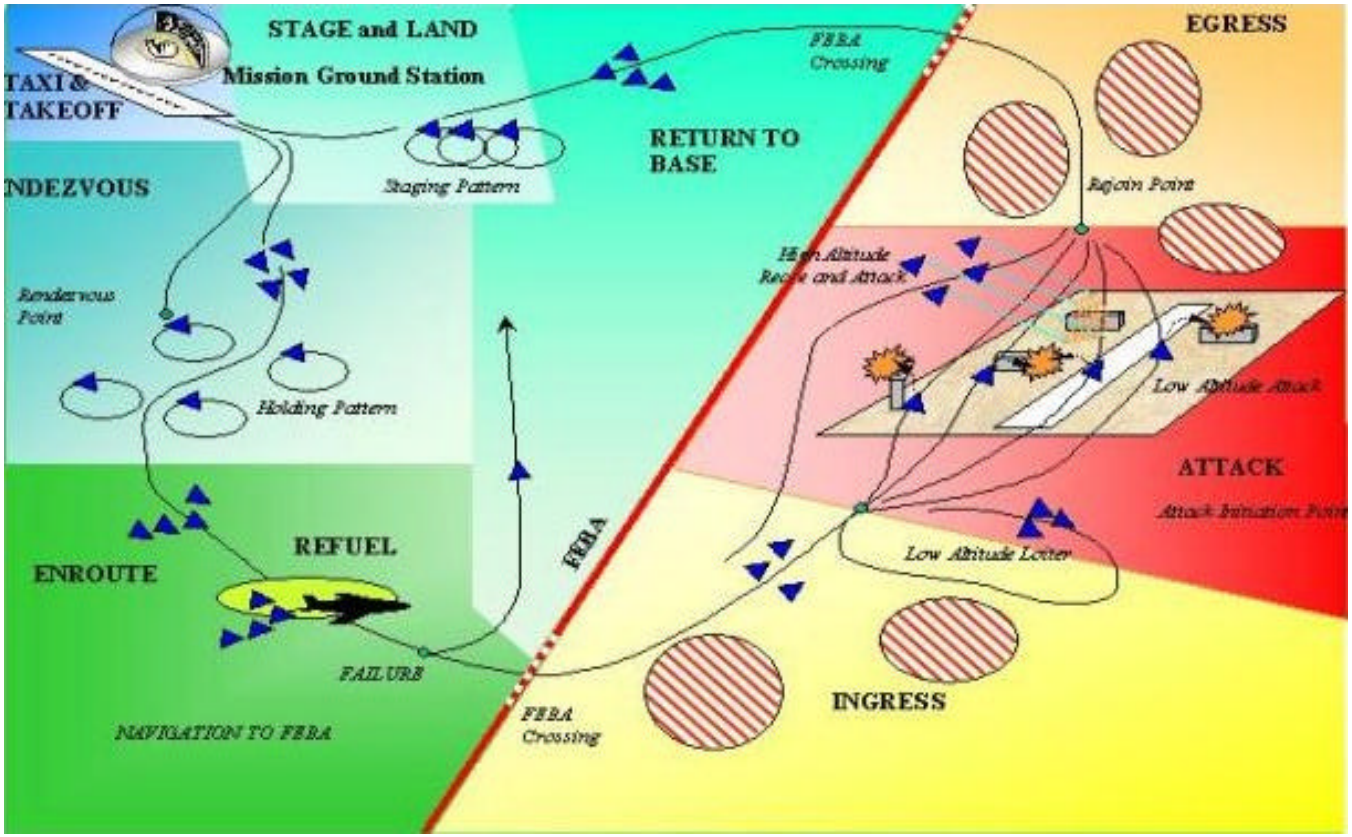
Air Force Research Laboratory

Complete UAV Cooperative Aerospace Operations

U.S. AIR FORCE

AIR FORCE RESEARCH LABORATORY

Enabling capability for seamless integration of UAV's into the war fighter force structure



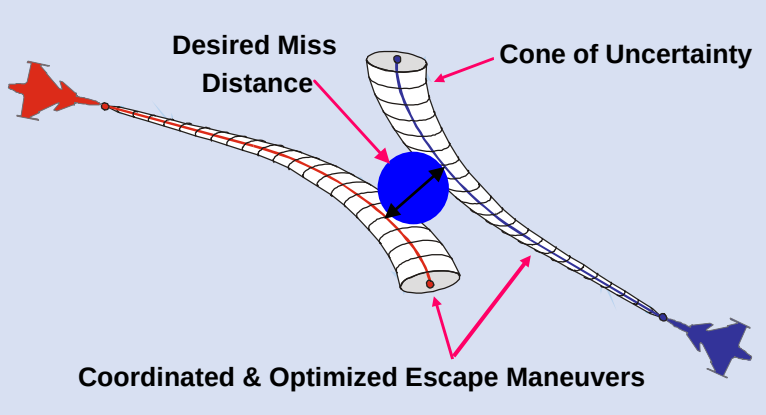
Airspace Operations

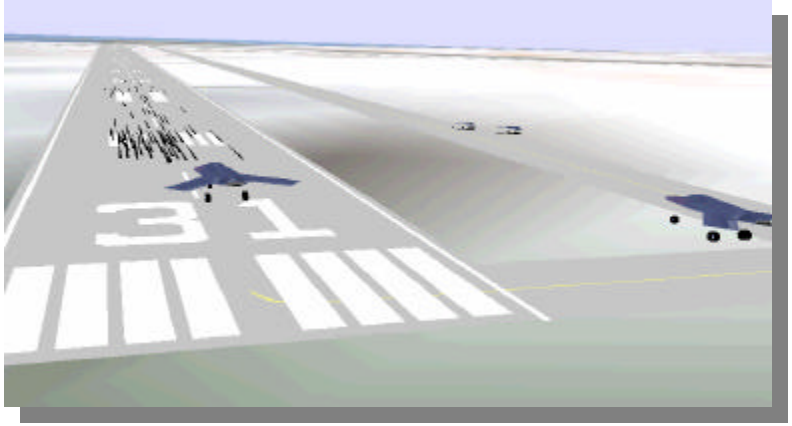
Persistent ISR

Strike UAV

Airspace Operations Capabilities

U.S. AIR FORCE





- **Goals:**
  - **Eliminate the 'specialness' associated with UAV's**
  - **Integrate seamlessly into emerging Air Traffic Control (ATC) System**
- **Challenges:**
  - **Capture the actions and procedures of pilots in the ATC (Normal and emergency)**
  - **Close proximity operations and real-time trajectory replanning, while also preventing mid-air collisions**

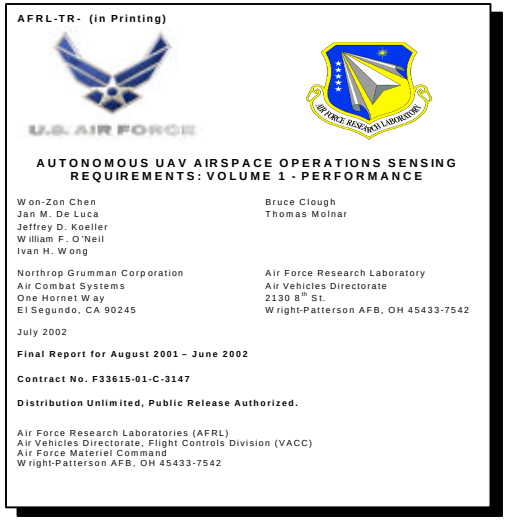
Same Time, Same Base, Same Tempo

VA Technologies that Enable Airspace Operations

U.S. AIR FORCE

Technology Innovation Enabling Airspace Operations

- **Autonomous Flight Control Sensing Technology**
- **Automatic Air Collision Avoidance System**
- **Control of Multi-Mission UAV Systems**



AFRL-TR- (in Printing)

U.S. AIR FORCE

AUTONOMOUS UAV AIRSPACE OPERATIONS SENSING REQUIREMENTS: VOLUME 1 - PERFORMANCE

Won-Zon Chen
Jan M. De Luca
Jeffrey D. Koeller
William F. O'Neil
Ivan H. Wong

Northrop Grumman Corporation
Air Combat Systems
One Hornet Way
El Segundo, CA 90245

Bruce Clough
Thomas Molnar

Air Force Research Laboratory
Air Vehicles Directorate
2130 8th St.
Wright-Patterson AFB, OH 45433-7542

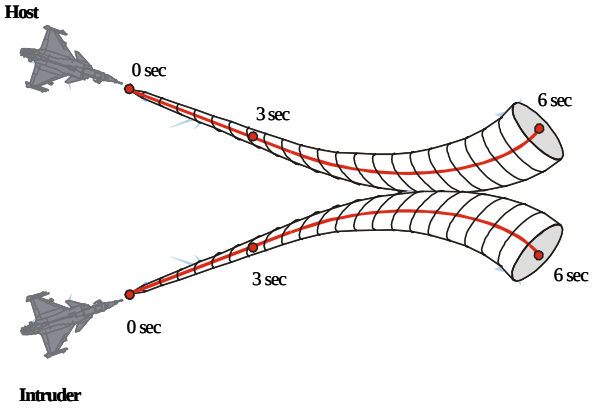
July 2002

Final Report for August 2001 – June 2002

Contract No. F33615-01-C-3147

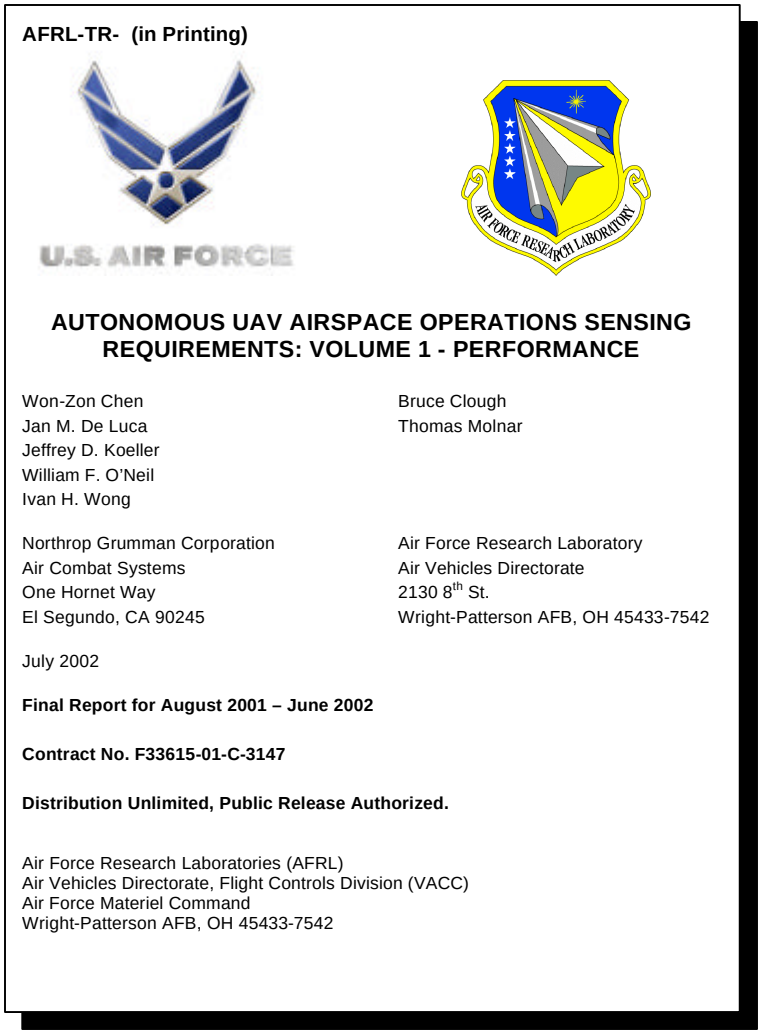
Distribution Unlimited, Public Release Authorized.

Air Force Research Laboratories (AFRL)
Air Vehicles Directorate, Flight Controls Division (VACC)
Air Force Materiel Command
Wright-Patterson AFB, OH 45433-7542



Airspace Sensing Requirements Generated

- **Report Written On Encouragement Of AIAA**
- **Established Sensing Performance Requirements For Commercial And Military UAV In US Airspace**
- **AIAA Presentation Sep 03**



AFRL-TR- (in Printing)

U.S. AIR FORCE

AIR FORCE RESEARCH LABORATORY

AUTONOMOUS UAV AIRSPACE OPERATIONS SENSING REQUIREMENTS: VOLUME 1 - PERFORMANCE

Won-Zon Chen
Jan M. De Luca
Jeffrey D. Koeller
William F. O'Neil
Ivan H. Wong

Bruce Clough
Thomas Molnar

Northrop Grumman Corporation
Air Combat Systems
One Hornet Way
El Segundo, CA 90245

Air Force Research Laboratory
Air Vehicles Directorate
2130 8th St.
Wright-Patterson AFB, OH 45433-7542

July 2002

Final Report for August 2001 – June 2002

Contract No. F33615-01-C-3147

Air Force Research Laboratories (AFRL)
Air Vehicles Directorate, Flight Controls Division (VACC)
Air Force Materiel Command
Wright-Patterson AFB, OH 45433-7542

U.S. AIR FORCE

Relationship to Access 5

ACCESS 5

Routine, safe, secure, and efficient HALE UAV operations in the National Airspace (NAS) within 5 years

- Near term emphasis:
  - Single operator – single vehicle
  - Commercial airspace
  - Limited set of airports
  - Longer timescale deconfliction

AFRL/VA

Make UAVs an integral part of military air operations:
"Same base, same time, same tempo"

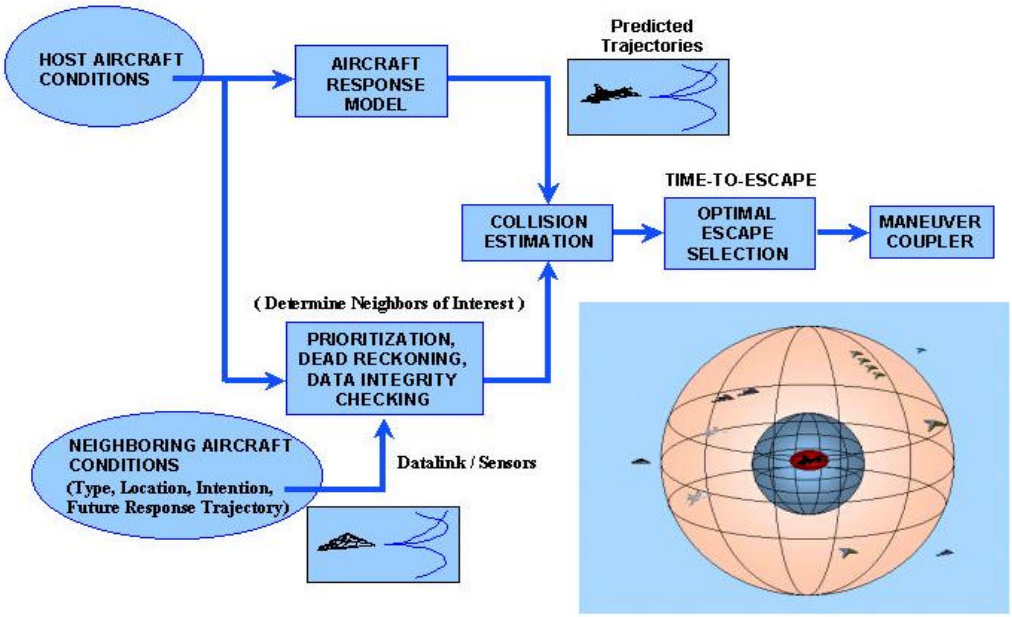
Near term emphasis:

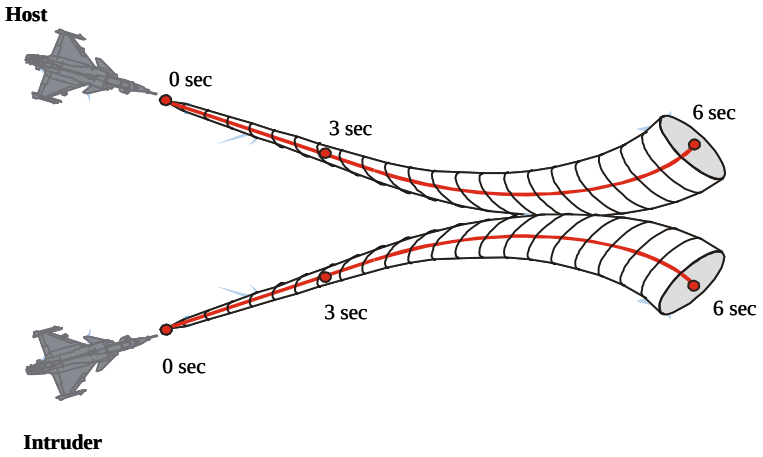
- Single operator – multiple vehicles
- Military airspace
- Mixed airspace, cooperative ops
- Short timescale collision avoidance
- Flight critical integration

Automatic Air Collision Avoidance System (Auto-ACAS)

U.S. AIR FORCE

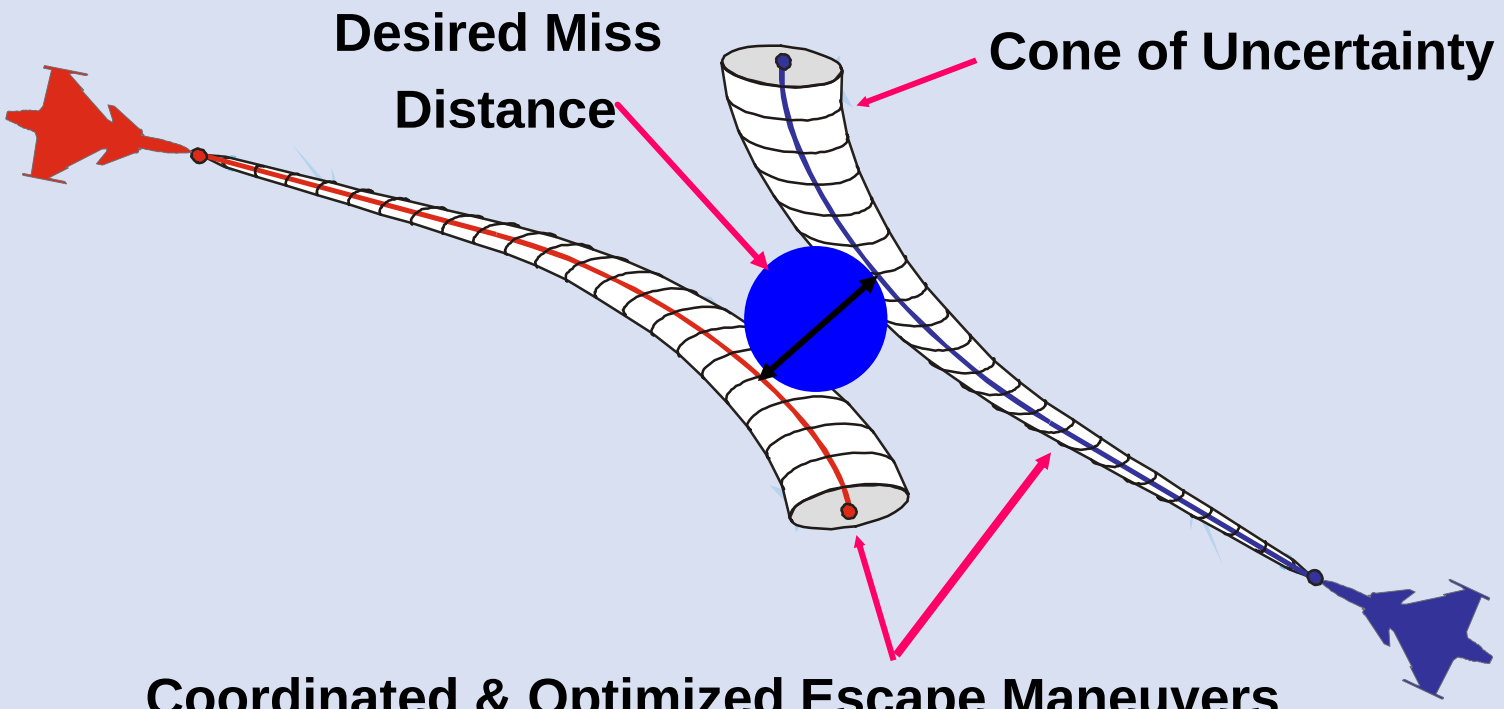
Auto ACAS Focus: Algorithm That Uses Information About Location & Trajectory Of Self and Others to Predict Collisions and Plan/Execute Avoidance





Automatic Air Collision Avoidance System

Data latency and positional uncertainty is addressed by safety cones



U.S. AIR FORCE

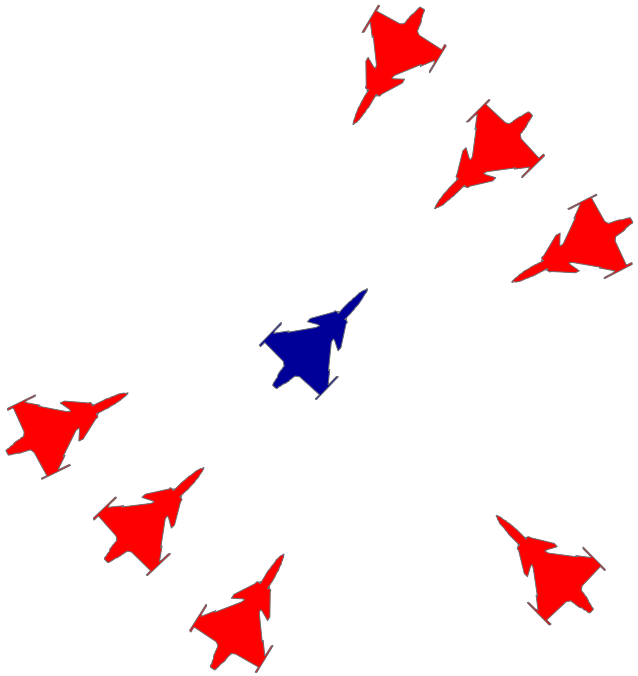
Auto-ACAS Flight Testing

AIR FORCE RESEARCH LABORATORY

33 Missions 43 Sorties 72.1 Flight Hours

Collision Runs

- 2-Ship Coop	33
- 2-Ship Non-Coop	9
- Virtual Fighter	327
- Virtual Multi-Ship	9
- Virtual UAV	7
- Pilot Activation	62



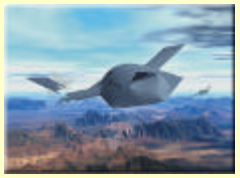
Algorithm operated successfully for all collision scenarios

Control of Multi-Mission UAV Systems

Open System Architecture VMS Computer

Reliable
Affordable
Adaptive
Autonomous

Multimode Fly-by-Light VMS



Health Management

Adaptive Control

- Compact, light weight, low cost VMS
- On-board, real-time, robust diagnostics
- Intelligent, adaptive flight control laws
- Intelligent, adaptive, cooperative flight management

Autonomous & Cooperative Flight/Mission Management (ACFMM)

Control of Multi-Mission UAV Systems

6 to 10-Vehicle Package

High Altitude Ops

Federated Management within Achievable Bandwidth

Package Leader

Datalink

Package Management within SATCOM Link Bandwidth

Mission Critical

VMS Computer

Event-Driven Middleware

IVHM

ACFMM

Time-Critical Middleware

Actuation (Control)

Adaptive Control

Optical Cable Plant

Actuation (EMA)

Flight Critical

Low Altitude Ops

Single Controller

VMS Hardware and Software

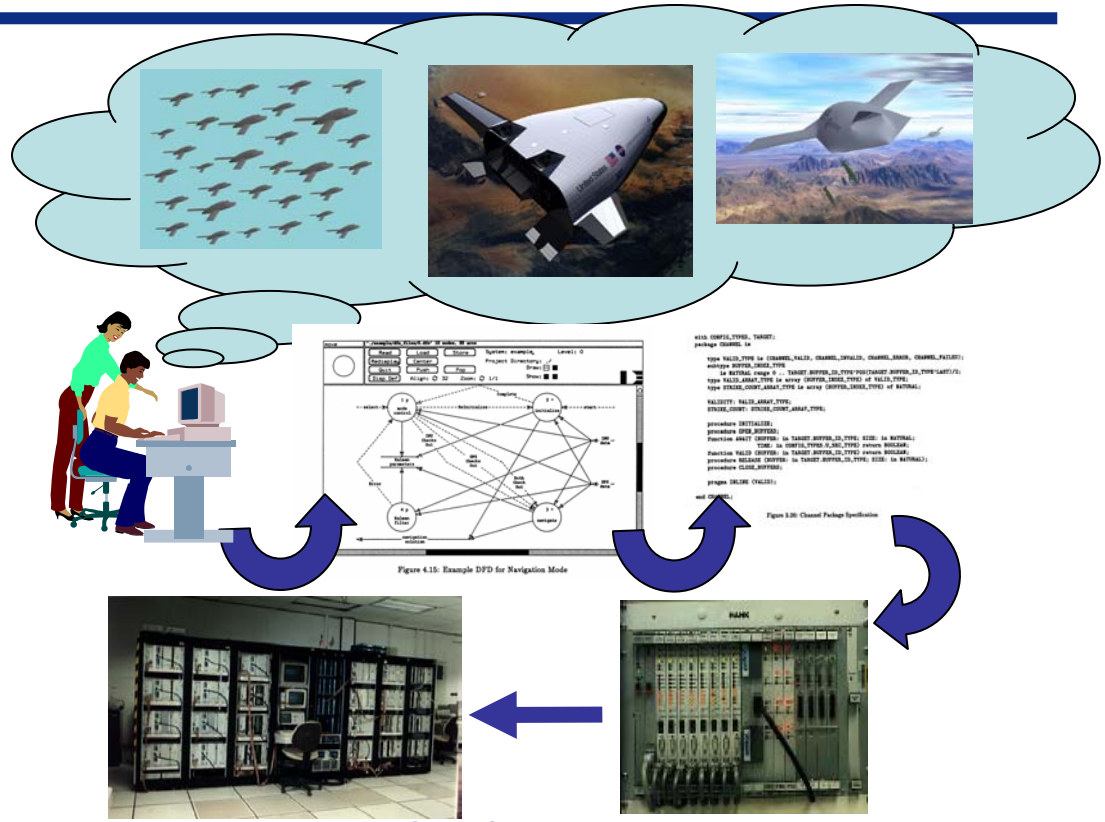
SEAD/Strike

Objective: Demonstrate TRL 6 maturity of critical integrated technologies to achieve reliable, affordable, adaptive, autonomous control for effective multi-ship combat UAV operations

Systems and Software Validation and Verification

U.S. AIR FORCE

AIR FORCE RESEARCH LABORATORY



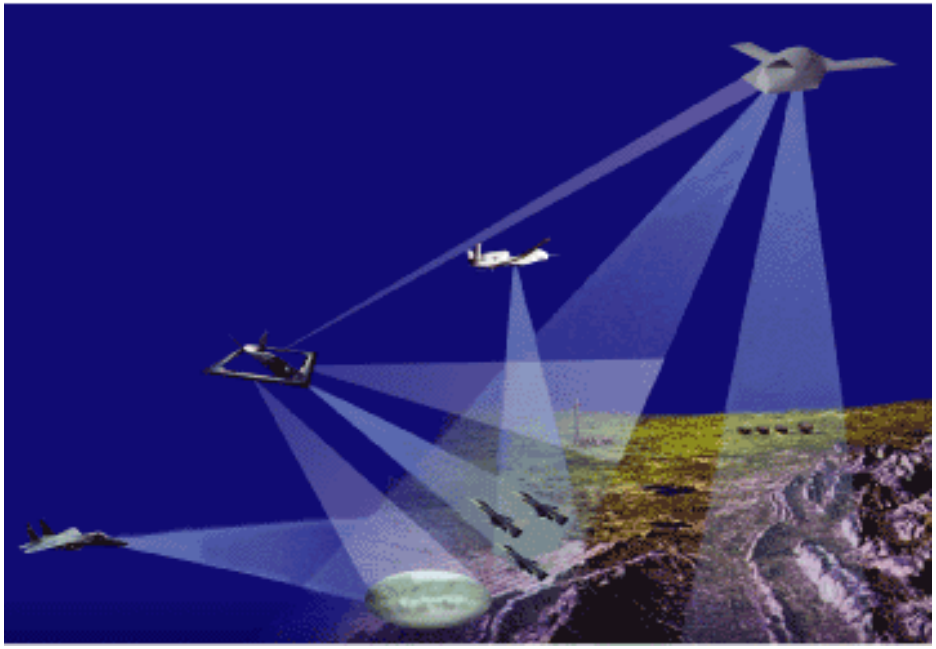
Today: *Software is a major cost/schedule driver for flight critical systems*

Tomorrow: *Advanced adaptive & autonomous algorithms can have nondeterministic behavior, making V&V difficult, if not unaffordable, given today's capabilities*

Persistent ISR Capabilities

U.S. AIR FORCE

- Goals:
  - Air defense
  - Concealed ground targets
    - Moving & stationary
  - TBM defense
  - Battlespace awareness
- Challenges:
  - 360 degree coverage
  - On Station 24/7
  - Multi-function/Multi-sensor
  - Foliage penetration
  - Integrated/Fused data



Detect and track every target that moves on the ground or flies in the battlespace…
anywhere, at any time

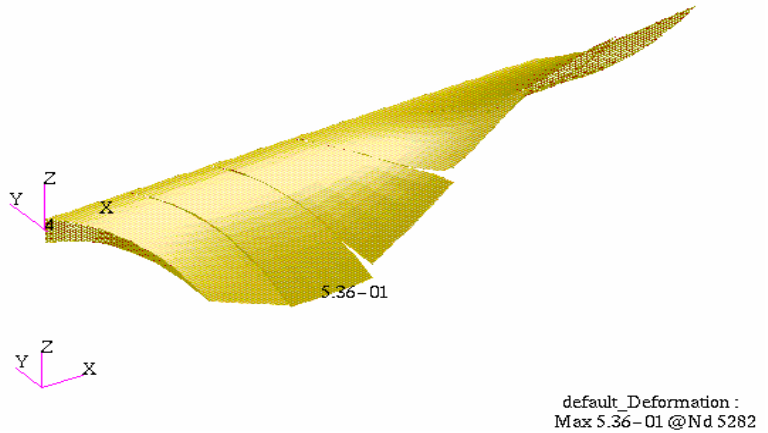
VA Technologies that Enable Persistent ISR

U.S. AIR FORCE

AIR FORCE RESEARCH LABORATORY

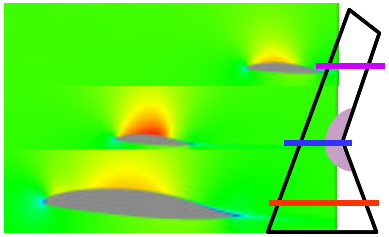
Technology Innovation Enabling Persistent ISR

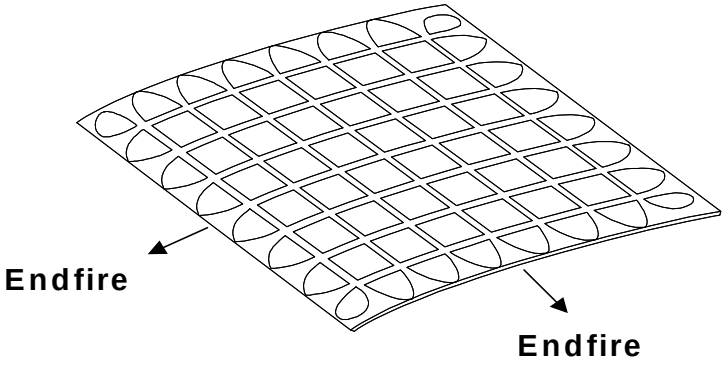
- **Advanced Aerodynamics**



- **Structurally Integrated Antennas**

- **Adaptive Structures**





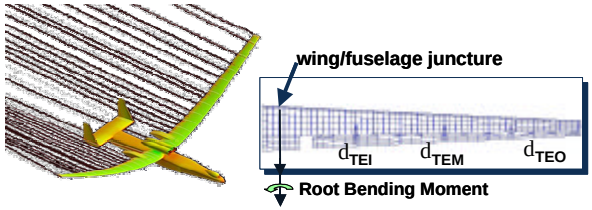
Advanced Aerodynamics Enables Persistence

U.S. AIR FORCE

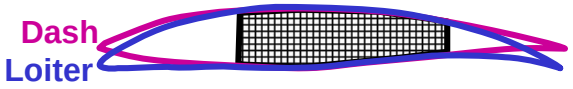
AIR FORCE RESEARCH LABORATORY

Active Aeroelastic Wing Deformation Management

- Aerodynamic Efficiency
- Manage Structural Loads
- Gust Load Alleviation

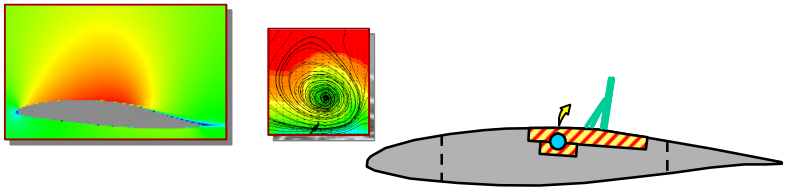


Physical Shape Change for Multipoint Optimization

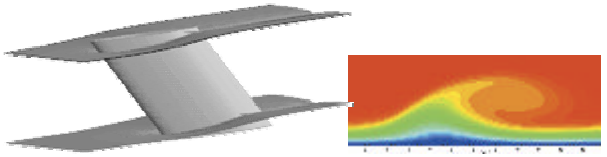


Active Separation Control

- Aggressive Airfoil Design
- Shock-Induced Separation



Transition Control (Swept Wing Laminar Flow Control)

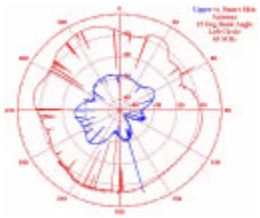


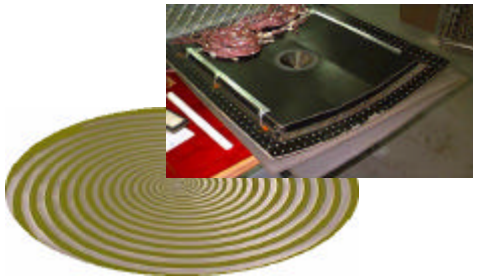
Structurally Integrated Antennas

U.S. AIR FORCE

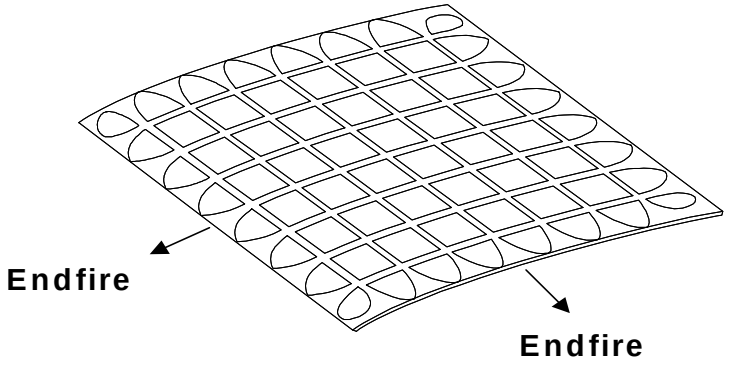
AIR FORCE RESEARCH LABORATORY

Wide-Band COMM Antennas Eliminate Blade Antennas and Dishes

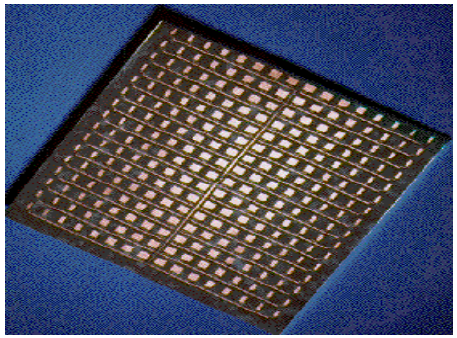




End-fire Technology Enables Large Low Band Antenna in Wing



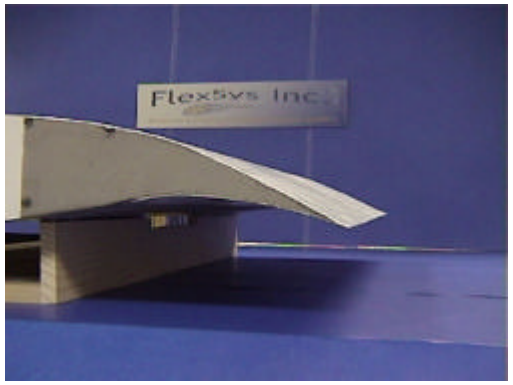
Light weight, low-cost X-Band Array Integrated into Aircraft Skins

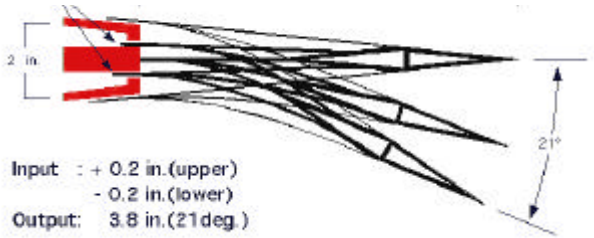


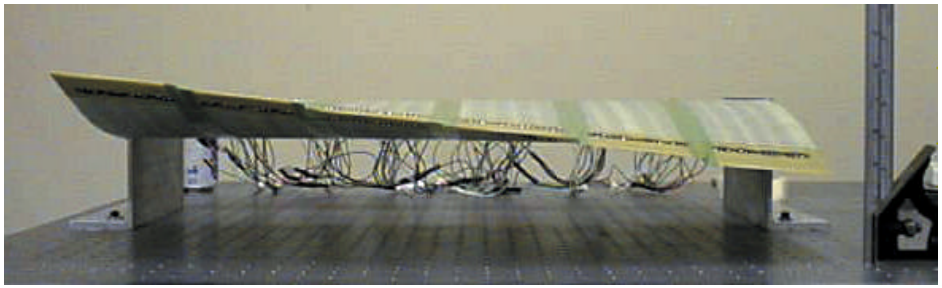
U.S. AIR FORCE

Adaptive Structures

- **Shape changing airfoils**
  - **Enables aero performance across broad flight regime**
  - **Provides control when room for control surfaces is limited**
  - **Improves maneuver performance**







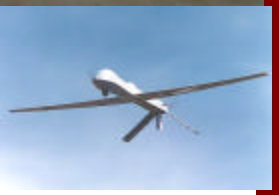
Strike UAV Capabilities

U.S. AIR FORCE

AIR FORCE RESEARCH LABORATORY

Capability First Gen Strike UAV

- J-UCAS X-45
- SEAD/DEAD
- Initial Aerial Refueling
- Initial "SEE/AVOID"
- Multiple vehicle per operator



Capability Second Gen Strike UAV

- Deep Strike
- Full Aerial Refueling Capability
- Electronic Attack
- Reduced footprint
- Flexible Mission Control
- Dynamic Mission Planning

Capability Advanced Strike UAV

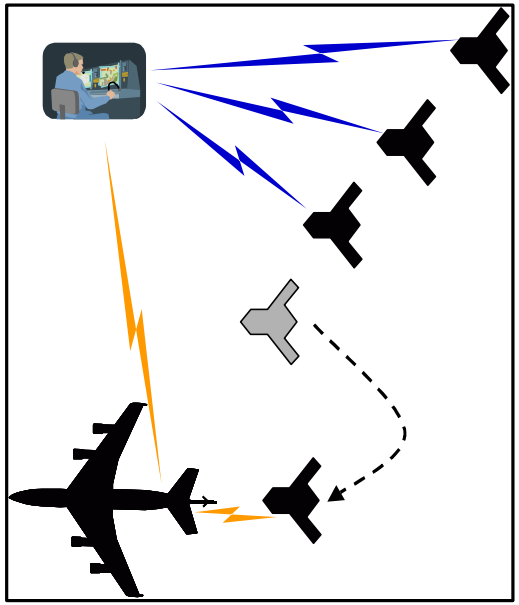
- Directed Energy
- Collaborative "Swarms"
- Seamless Airspace Operations
- Interactive Autonomy
- Mixed Operations
- Information fusion
- "Self-Situational Awareness"
- Beyond J-UCAS ???

VA Technologies that Enable "Strike UAV"

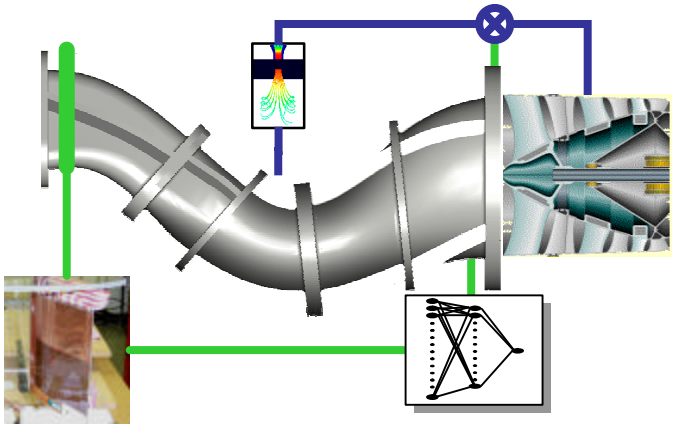
U.S. AIR FORCE

Technology Innovation Enabling Strike UAV's

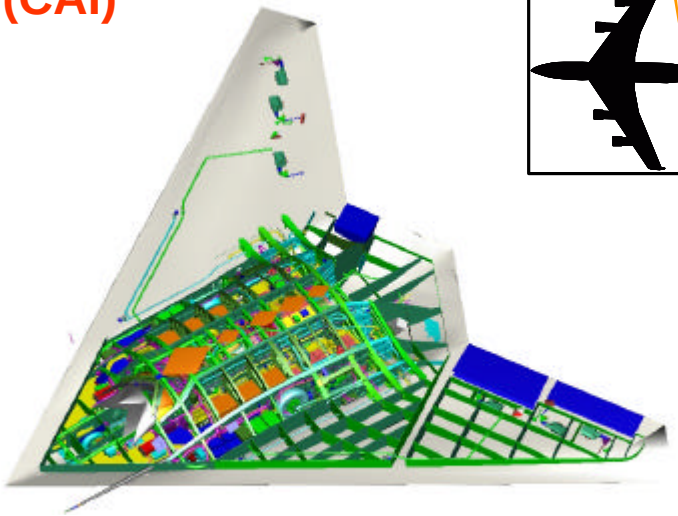
- **Automatic Aerial Refueling**



- **Structurally Integrated Compact Inlet Technology**

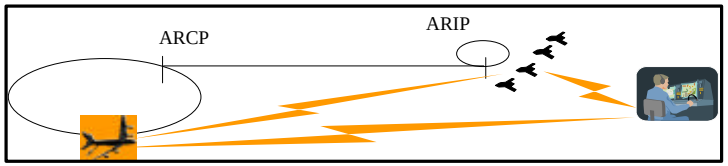


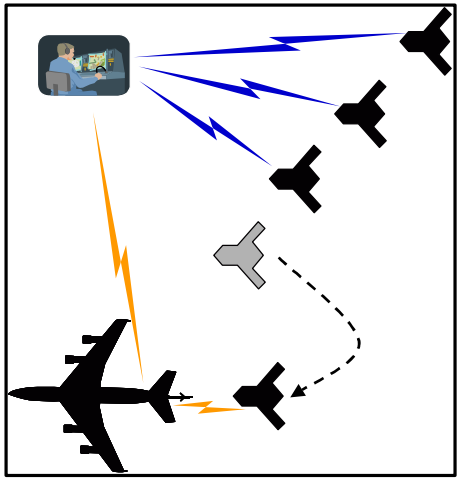
- **Composites Affordability Initiative (CAI)**



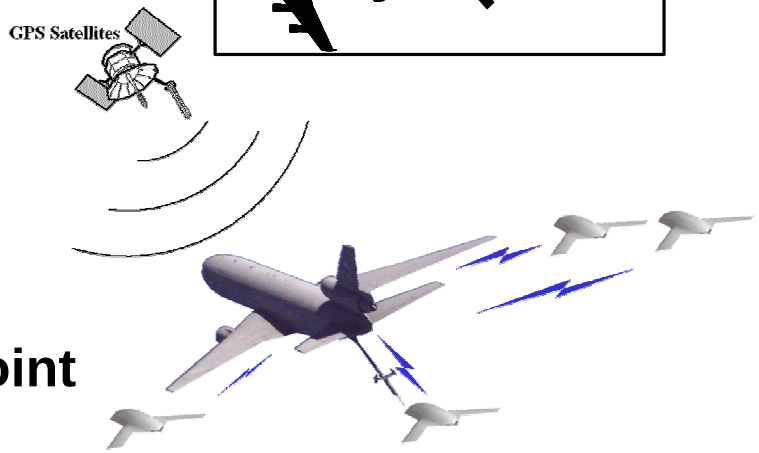
U.S. AIR FORCE

Auto Air Refueling (AAR)





- **VA is the World's Leader in AAR**
- **Operationally Relevant (Navigation & Sensing Based Solutions)**
- **Meet J-UCAS Transition Schedule (New Joint AAR Initiative is Underway)**



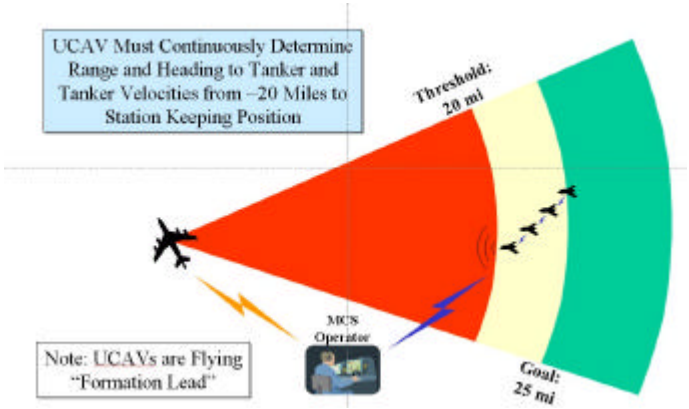
U.S. AIR FORCE

AAR Tech Challenges

AIR FORCE RESEARCH LABORATORY

See Far

- Determine Tanker Location from "Far Away"
  - Detect/Track Tanker in Tanker Cell
  - Approx 50 Mile Range



See Near

- Determine Relative Position with Tanker
  - Using Position/Velocities to Close Control Loop
  - High Confidence in Position Accuracy

Command and Control

- Assure J-UCAS Accurately Responds Boomer Break-Away Commands
  - Commands are Flight Critical

Real World Considerations

- Fitting Solutions into a Low Probability of Detect/Intercept Environment
  - Latency, Drop-Outs, Re-Encryption, and Limit Power Settings

U.S. AIR FORCE

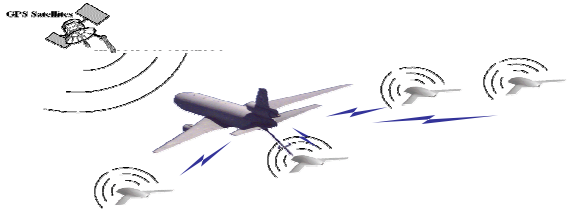
Technical Approaches

AIR FORCE RESEARCH LABORATORY

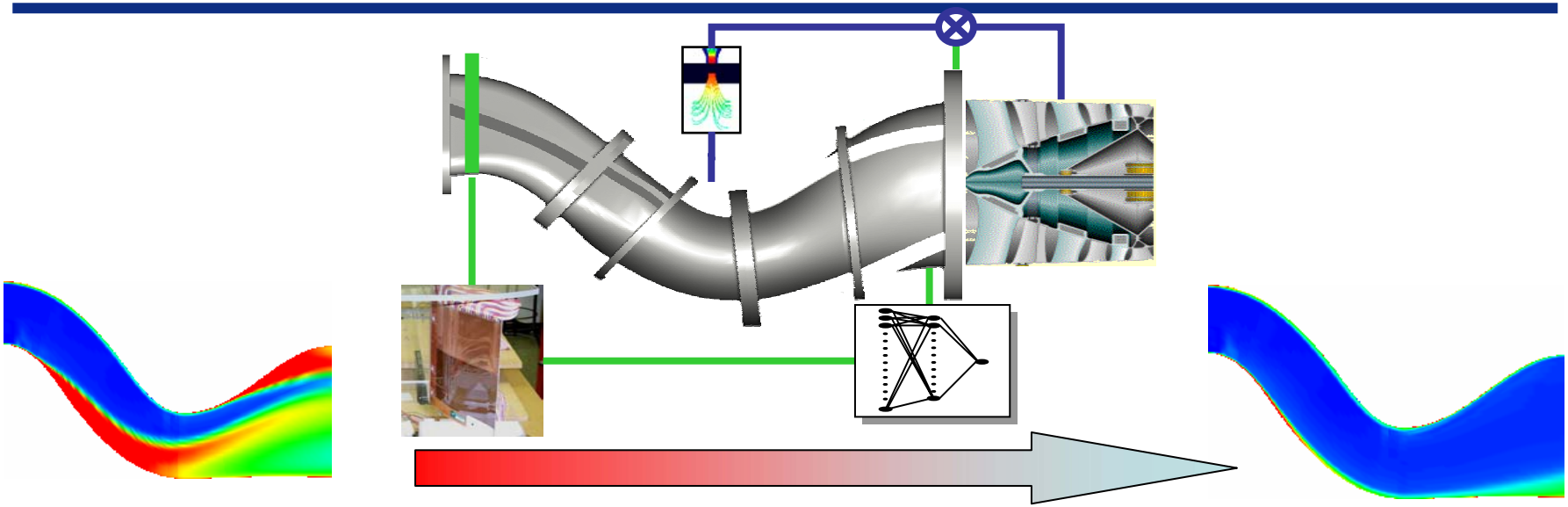
- Precision Navigation – Use Precision GPS/INS
  - Rendezvous with tanker
  - Maneuvering Around Tanker

- Sensor Based Approach
  - Limited Rendezvous Capability
  - Maneuvering Around Tanker

- Hybrid Design – Standard GPS + Sensor
  - Rendezvous with Tanker – GPS
  - Maneuvering Around Tanker – Sensor

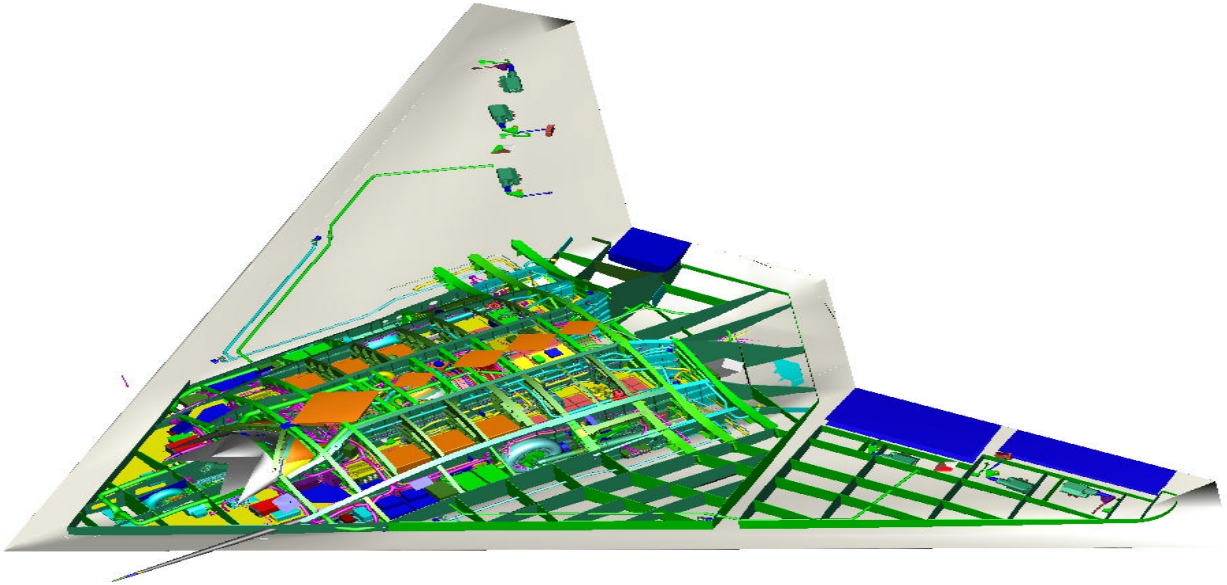


Structurally Integrated Compact Inlet Technology (STRICT)



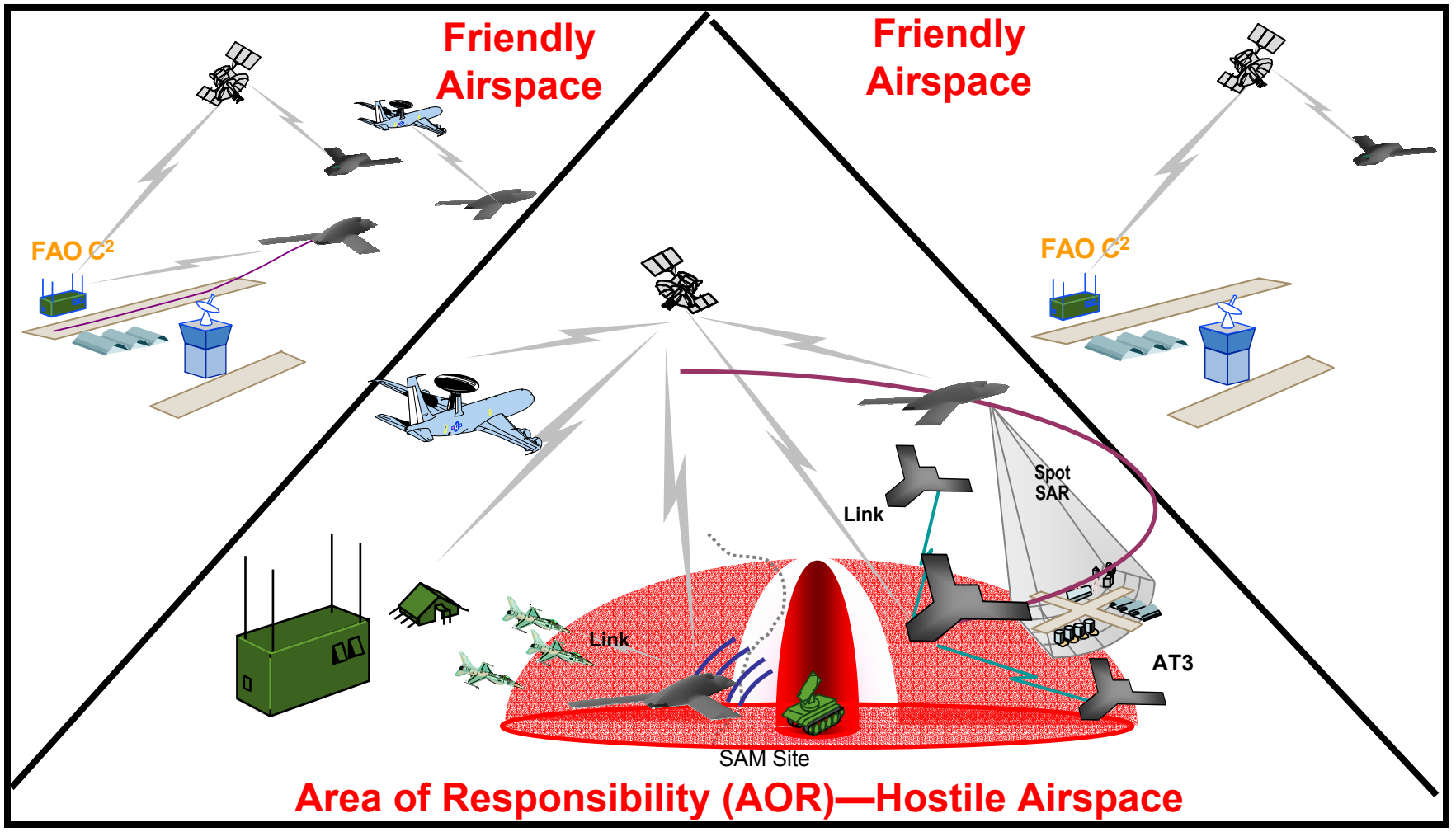
- **STRICT is VA's first step into Active Integrated Inlet Technology:**
  - **Reduced weight – downsize vehicle or reduce volume of the engine**
  - **Increase installed thrust**
  - **Reduce high-cycle fatigue**
  - **Latitude in center of gravity location**

Composites Affordability Initiative (CAI)



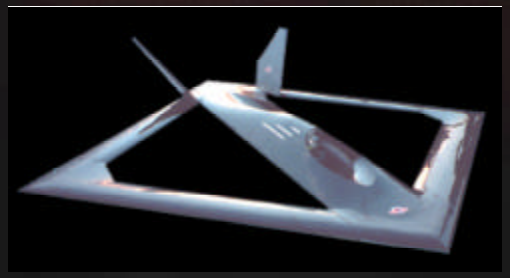
- **Improve structures technology that will lead to:**
  - **Paradigm change – We no longer have to pay to reduce weight**
  - **Reduced cost to manufacture, operate, and support**
  - **Increase range, payload, and performance by reducing weight**

Complete Mission Operations



Air Vehicles Directorate

. . . 100 years of flight and counting . . .



"We give the Air Force its Wings"

Backups

U.S. AIR FORCE

Autonomy Continuum